REVIEW ARTICLE

CONTENTS

Periarticular artery embolization as a minimally invasive treatment for pain in osteoarthritis

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ABSTRACT

Osteoarthritis (OA) is a leading cause of chronic pain and disability worldwide, affecting approximately 607 million people in 2021, with projections exceeding 1.1 billion by 2050. The knee is the most commonly affected joint and many patients experience inadequate symptom relief with conservative management or are not candidates for total knee arthroplasty. Periarticular arterial embolization, particularly genicular artery embolization (GAE), has emerged as a minimally invasive treatment targeting pathological neovascularization and synovial inflammation in OA pathogenesis. This review aims to synthesize current evidence on the use of periarticular embolization in the treatment of OA across multiple joints including the knee, hip, shoulder, hand and temporomandibular joint (TMJ). A comprehensive literature review was conducted examining clinical studies, systematic reviews and meta-analyses evaluating periarticular artery embolization for OA treatment. Periarticular artery embolization represents a promising minimally invasive treatment option for patients with mild-to-moderate OA who have failed conservative therapy. It demonstrates high technical success rates (approaching 100%) with favourable safety profiles for knee OA, with emerging applications in other joints. However, standardized procedural protocols, long-term outcome data and multicenter randomized control trials are needed to definitively establish its role in OA treatment and optimize patient selection criteria.

KEY WORDS: genicular artery embolization, transarterial embolization, periarticular embolization

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INTRODUCTION

OA is the most prevalent form of arthritis globally, affecting approximately 607 million people worldwide in 2021. The knee is the most commonly affected joint, with more than 37% of Americans over age 60 experiencing chronic pain from knee OA [1]. It has been projected that by 2050 over 1.1 billion individuals will be affected by OA, driven by population aging and increasing obesity rates [2]. OA represents a leading cause of chronic pain and disability, particularly in older adults, creating substantial limitations in mobility and quality of life (QOL) and imposing a significant economic burden on healthcare systems [2]. Progressive synovial inflammation and neoangiogenesis play a critical role in OA pain through synovial lining hyperplasia, macrophage and lymphocyte infiltration, neoangiogenesis and fibrosis. These changes correlate with more severe pain and joint dysfunction and may predict faster rates of cartilage loss [2].

Current treatment paradigms for symptomatic OA primarily rely on conservative management, including patient education, exercise, weight loss and pharmacological interventions [2]. However, many patients experience inadequate symptom relief with these measures alone [2]. Gold standard alternative therapy for OA of the knee is a total knee arthroplasty (TKA), although many patients are not ready for surgery or have comorbidities that preclude surgical candidacy [3]. This treatment gap has driven the search for minimally invasive alternatives.

Periarticular arterial embolization is a minimally invasive, image-guided procedure targeting abnormal neovascularization and synovial inflammation implicated in OA pathogenesis. The most extensively studied proce-

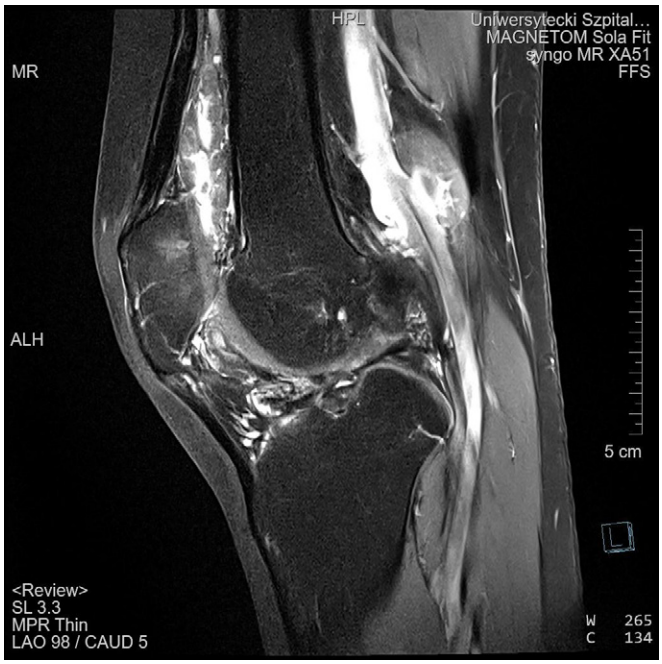

Fig. 1. Angiography of the popliteal artery prior to embolization, showing embolus causing significant impairment of blood flow, classic for knee OA. *Source: Own materials*

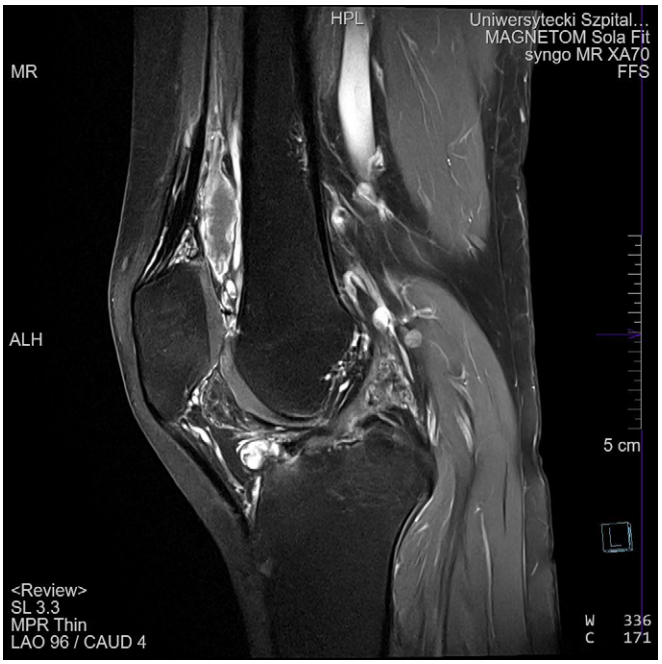

Fig. 2. Angiography of the popliteal artery after embolization demonstrating successful occlusion of the vessel lumen with absence of distal flow *Source: Own materials*

dure is genicular artery embolization (GAE) for knee OA. The procedure selectively occludes pathologic periarticular vessels, aiming to disrupt the cycle of inflammation and nociceptive signaling, thereby reducing pain and improving function [4]. Periarticular arterial embolization represents a potentially valuable treatment option for patients with mild-to-moderate OA who have exhausted conservative treatment options, warranting further investigation to define its role in OA treatment [4].

AIM

The aim of this study is to provide a review of current data on the use of periarticular embolization in the treatment of osteoarthritis of different joints.

MATERIALS AND METHODS

A comprehensive literature search was conducted across multiple electronic databases including PubMed, Embase and Cochrane library from 2021 through January 2025, to identify studies on periarticular embolization for OA treatment. Search terms included "osteoarthritis", "genicular artery embolization", "transarterial embolization", "periarterial embolization", "TAPE", "knee osteoarthritis", "hip osteoarthritis" and related variations. We included systematic reviews and meta-analyses, randomized controlled trials, prospective and retrospective original research, narrative review, protocol papers and case series.

REVIEW

Periarticular artery embolization is performed via femoral or radial arterial access using fluoroscopic guidance, with selective catheterization of periarticular arteries using microcatherters [4, 5]. Prior to the procedure, digital subtraction angiography is performed to identify abnormal hyperemia and neovascularization, as seen in Figure 1 [4, 5]. These pathologic vessels are then occluded using embolic agents while preserving normal arterial inflow, as seen in Figure 2 [4, 5]. Arresting the pathological neoangiogenesis to the inflamed synovium and nociceptive subchondral bone disrupts the inflammatory cascade and prevents pathological neoinnervation that drives OA pain [4, 5]. Biomarker studies demonstrate that GAE reduces serum levels of vascular endothelial growth factor (VEGF), nerve growth factor (NGF) and interleukin receptor antagonist (IL-1Ra), suggesting both anti-inflammatory and anti-nociceptive effects that contribute to sustained pain relief [6].

GAE is the best documented application of periarticular artery embolization for OA, with robust evidence from prospective studies, systematic reviews and guidelines supporting its use for knee OA pain refractory to conservative therapy [7]. Safety profiles are favorable for GAE, with high technical success rates and mostly mild, self-limited adverse events [7]. Most studies report improvements in pain scores (VAS, WOMAC, KOOS) sustained up to 12 months [5, 7].

EMBOLIZATION IN KNEE OSTEOARTHRITIS

GAE demonstrates high technical success rates, a favourable safety profile and significant reduction in knee OA pain [7]. A systematic review and meta-analysis evaluating 10 studies encompassing 351 treated knees demonstrated that GAE provides durable reduction in pain scores across all OA severity grades [7]. Patients who underwent GAE showed significant declines in VAS pain scores at 1 month (-34 points), 3 months (-30 points), 6 months (-41 points) and 12 months (-37 points) [7]. The effect sizes (Hedges' g) ranged from -1.2 to -1.4 across follow-up intervals, indicating large and clinically meaningful treatment effects [7]. A more recent meta-analysis of 14 studies (510 patients, 567 knees) confirmed these findings, reporting pooled pre-post pain reductions of approximately 30 points on a 0-100 scale at 6-12 months, with 78-92% of patients achieving clinically meaningful improvement (>50% pain reduction or ≥ 10-15 point change) by 1 year post-procedure [8].

Comprehensive reviews confirm that GAE consistently achieves high technical success rates with improved VAS, WOMAC and KOOS metrics at short- to mid-term follow-ups [5]. Beyond pain relief, GAE significantly improves joint function and physical capacity. A systematic review of 17 studies (533 patients, 620 knees) reported mean improvements at 12 months for VAS ranging from 10 to 59 points and WOMAC scores, which encompasses pain, stiffness and physical function, ranging from 35.3 to 47 points, with additional improvements in KOOS subscales including Pain, Quality of life, sport and symptoms [9]. Prospective data demonstrate that WOMAC scores decreased significantly from 49.4 at baseline to 27.4 at 12 months in patients with mild to moderate OA ($p<0.001$) representing a 45% improvement in overall joint function [10].Notably patients with mild-to-moderate OA demonstrated better outcomes than those with severe disease, and decreasing minimal clinically important difference (MCID) achievement was observed between 3 and 6 months, suggesting that patient selection may influence durability of response [9,10].

Prospective trial data further support these findings. In an interim analysis of a single-arm prospective trial using 250-um microspheres, technical success was achieved in 100% of procedures, with 83% of patients (5 of 6) achieving the MCID for WOMAC pain score at 12 months [6]. Notably, biomarker analysis revealed a statistically significant decrease in nerve growth factor (NGF) levels at 12 months, suggesting that GAE may contribute to pain reduction through anti-nociceptive mechanisms and potentially slowing cartilage degeneration [6]. Both temporary and permanent embolic agents have demonstrated comparable clinical results, though variability in vessel targets, embolic particle size and periprocedural protocols across studies limits direct comparisons and pooled analyses [5].

GAE safety profile is favourable and reported complications are uncommon and typically resolve without interventions [4, 5]. The most common adverse events include: Transient skin discoloration or erythema at the embolication site, which typically resolves spontaneously within days to weeks, self-limited paresthesias in the distribution of cutaneous nerves, minor access site complications such as hematoma or bruising at the femoral or radial puncture site, and transient post-procedural pain or swelling of the treated knee [5, 8, 9]. In prospective trials, no major adverse events have been reported [6]. Serious complications such as non-target embolization causing skin necrosis, muscle infarction or nerve injury are rare when proper technique is employed, including careful angiographic assessment prior to embolization and use of appropriately sized embolic particles [4, 5]. Current evidence supports GAE as a safe and efficacious treatment for symptomatic knee OA refractory to conservative management [4-7]. However, standardized procedural methods, uniform outcome reporting and robust multicenter randomized controlled trials are needed to confirm long-term safety and efficacy, optimize patient selection and criteria and definitively establish GAE's role within the knee OA treatment algorithm [5].

EMBOLIZATION IN SHOULDER OSTEOARTHRITIS

Documented cases of therapeutic embolization of the shoulder joint for relief of osteoarthritic symptoms are rare. One case report describes a patient suffering from shoulder OA who was treated with transarterial periarticular embolization (TAPE) [16]. VAS preprocedure was 7 during the day and 8 at night, and the American Shoulder and Elbow Surgeons (ASES) score was 34.3. Severe restrictions in anteversion (90 degrees), and abduction (passive - 80 degrees, active - 40 degrees) were present [16]. Access was gained through the radial artery and a catheter was guided to the target anterior and posterior circumflex humeral branches, coracoid branch, and circumflex scapular artery. Upon discharge, significant pain relief was present (VAS score - 4 daytime and 0 night; ASES score - 63.3), and significant mobility improvements were seen (anteversion - 180 degrees; passive abduction - 160 degrees, active abduction - 120 degrees) [16]. However, due to the nature and size of this study, its use is limited, and can only be interpreted as a prognostic factor for the future use of therapeutic embolization in joint pain relief and mobility improvements in patients with OA.

EMBOLIZATION IN HIP OSTEOARTHRITIS

In a prospective, single-arm trial, 18 patients with a mean age of 67.2 ± 5.7 years underwent transarterial embolization (TAE) due to contraindications for total hip arthroplasty [14]. Currently, patients who don't qualify for total hip arthroplasty (THA) (up to 30% of patients), are confined to conservative treatment such as intra-articular injections, platelet-rich plasma, and nerve blocks. Therefore, the possibility of TAE for osteoarthritic pain and dysfunctionality of the hip to become mainstream would benefit a large population [14]. Brachial access was obtained and the catheter was guided to the lateral circumflex femoral artery (LCFA) targeted for hip TAE. VAS and Harris-Hip Score (HHS) were assessed at 0 weeks, 4 weeks, 8 weeks, and 12 weeks. HHS improved by 14.4 points post-op (45.5 ± 4.7 to 59.9 ± 7.1, p<0.01), and the increase concluded at week 8 (62.6 ± 6.0). The scores remained stable at week 12, showing early benefit and stable outcomes. The VAS score shared a similar improvement, decreasing post-op (7.8 ± 1.3 to 4.2 ± 2.0, p<0.01), improved by week 8 (3.7 ± 2.7), and concluded at week 12 at 4.3 ± 2.2, showing significant and sustained reduction in pain. [14]. Due to the small cohort (n=18) and no control group, it is impossible to determine long term effectiveness and predictability in the general population without larger scale studies.

A single-center prospective cohort analysed the long term effects of TAE of the hip in 13 patients spanning over 6 months using VAS and WOMAC [15]. Preprocedure VAS score on average was 10, and after 6 months 3 points, p=0.002. WOMAC score had a statistically significant decrease from a mean 77 preprocedure to 27 points after 6 months, p=0.001. There were no long term side effects noted, with one patient presenting a small groin hematoma which spontaneously resolved after 15 days and two patients had posterior thigh numbness resolving in 21 and 30 days [15].

Due to lack of published data, there are a few notable limitations to TAE of the hip. The tumor-like blush signifying abnormal neovasculature, especially in knee osteoarthritis, is not commonly present, making identification of abnormal angiogenesis difficult. Instead, corkscrew-like arteries are more common [15]. There is also an unknown risk of aseptic hip necrosis (AHN). In TAE of the LCFA, imipenem/cilastatin embolic agent is preferred due to the lowest risk of ischemia, however, there is no documented long term proof of efficacy or risk of AHN occurrence in LCFA [15].

EMBOLIZATION IN OTHER LOCATIONS

More unconventional locations in therapeutic embolization to treat osteoarthritic symptoms include the hands and temporomandibular joint (TMJ). In a retrospective cohort pilot study conducted on 9 patients with osteoarthritic hand pain, overall VAS scores significantly decreased at 1-week, 1-month, 3-months, and 6-months after TAE (34 ± 18mm, P<0.001; 32 ± 11mm, p<0.001; 21 ± 15mm, P<0.001; 18 ± 19mm, P = 0.002) [11]. Cannula insertion was performed into the distal radial artery and advanced anterograde, with two sessions scheduled for each patient, the second at 1-month after the first TAE [11]. Responders to treatment were defined as patients with a ≥50% pain reduction, and measured at the above-mentioned timeframes they were 66.7%, 77.8%, 88.9% respectively [11,12]. 100% of the patients reported significant decrease in joint restriction, with 75% of these patients unsuccessfully undergoing steroid injection therapy prior to TAE [12] The only adverse effect reported was early recurrence of joint pain in 44% of patients, potentially due to partial recanalization of abnormal vessels or revascularization. However, this was milder than before TAE treatment [11]. Some limitations to these studies include no restriction on the use of conservative therapy after treatment and the lack of a control group [11]. The small sample sizes (9 patients and 4 patients) are unlikely to accurately represent the broader population [12].

In a retrospective case series involving 3 patients with TMJ osteoarthritic pain and dysfunctionality, TAE was performed after referral from oral maxillofacial surgeons [13]. Arterial access was obtained through the femoral artery and a microcatheter was guided into the proximal part of the superficial temporal artery [13]. Postprocedure the patients were assessed using the NRS as well as the Oral Health Impact Profile - Temporomandibular Joint (OHIP-TMJ) questionnaire, and outcomes were measured at baseline, 6 weeks, and 3 months. OHIP-TMJ score decreased from 38, 45 and 45 to 31, 39, and 28, respectively. NRS scores improved from 9, 10, and 9 to 7, 7, and 5, respectively. Joint function improved in all 3 patients, however, patient 2 only showed temporary improvement in joint function [13].

DISCUSSION

The pathophysiology of osteoarthritis centers around degradation of the cartilage, synovium, and subchondral bone due to mechanical stress and inflammation. However, imaging evidence also points to vascular contribution to disease progression [14]. Increased interosseous pressure contributes to amplified degradation of subchondral bone, and upregulated vascular endothelial growth factor leads to increased neovasculature accompanied by sensory nerve branches [4, 14]. These pierce normally avascular joint regions in areas

of increased mechanical stress, leading to nociceptive signalling and chronic pain. Superselective embolization of this neovasculature allows us to individually choose abnormal vessels causing pain and block them, inhibiting nociceptive signals and further vascular proliferation.

TAPE provides an excellent therapeutic choice for OA patients who have not had symptomatic improvement with conventional therapies. Its minimally invasive approach allows for faster patient recovery and better prognostic outcomes, and the procedure is much quicker (15-30 minutes) than the next therapeutic option (THA or TKA). More than 80% of patients have an observable improvement in function and QOL [3, 6, 15]. It also shows promise of an effective middle ground between conventional therapies with steroids, NSAIDs, physiotherapy and arthroplastic procedures. Since up to 30% of patients do not qualify for THA in hip OA, it would provide a much-needed therapeutic option for those. Currently, its main setback is the lack of published evidence confirming long-term benefits and efficacy. The most widely studied area of TAPE is genicular artery embolization, however, the longest period of patient monitoring we see is 12 months [8]. While no severe side effects were observed, there are concerns over slowly developing pathologies such as avascular necrosis (AVN). Other joints have even less data, with sample sizes not exceeding a few patients. So, while preliminary results are promising, our current data makes it impossible for us to predict outcomes on the general population and implement TAPE as a standard in the therapeutic ladder for OA.

As of now, there is no set criteria for qualifying patients with OA for periarticular artery embolization. It is purely based on individual circumstances and on physician's assessment. Some reports suggest that severity of OA may influence effectiveness of TAPE. Patients with mild to moderate OA may respond better than with severe OA [9, 10]. Inclusion criteria also vary within different studies, but commonly include older age (>60), prior ineffective management with 2+ conservative therapies, duration of symptoms >1 year, and 1+ contraindication for surgical management [14].

CONCLUSIONS

Transarterial periarticular embolization, especially involving the genicular arteries, has proven to be a safe and effective method for alleviating pain in osteoarthritis resistant to conservative treatment. Due to its relatively recent emergence, no standardized indications have been formulated for its use, currently being based only upon a physician's opinion. Minimal published data for other locations, indicates the need for more research prior to TAE becoming a mainstream therapy for OA. However, described cases show promise and therapeutic potential to expand to many other pain pathologies.

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COFLICT OF INTEREST

The Authors declare no conflict of interest

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